成果一.

我院黄飞敏研究员、王益研究员等与其合作者的论文 Time-asymptotic stability of composite waves of degenerate Oleinik shock and rarefaction for non-convex conservation laws 被 MATHEMATISCHE ANNALEN 接收发表。

摘要：

We are concerned with the large-time behavior of the solution to one-dimensional (1D) cubic non-convex scalar viscous conservation laws. Due to the inflection point of the cubic non-convex flux, the solution to the corresponding inviscid Riemann problem can be the composite wave of a degenerate Oleinik shock and a rarefaction wave and these two nonlinear waves are always attached together. We give a first proof of the time-asymptotic stability of this composite wave, up to a time-dependent shift to the viscous Oleinik shock, for the viscous equation. The Oleinik shock wave strength can be arbitrarily large. The main difficulty is due to the incompatibility of the time-asymptotic stability proof framework of individual viscous shock by the so-called anti-derivative method and the direct L^2-energy method to rarefaction wave. Here we develop a new type of a-contraction method with suitable weight function and the time-dependent shift to the viscous shock, which is motivated by Kang and Vasseur (Ann l'Institut Henri Poincaré C Analyse non lineaire 34(1):139156, 2017) and Kang et al. (Adv Math 419:108963, 2023). Another difficulty comes from that the Oleinik shock and rarefaction wave are always attached together and their wave interactions are very subtle. Therefore, the same time-dependent shift needs to be equipped to both Oleinik shock and rarefaction wave such that the wave interactions can be treated in our stability proof. Time-asymptotically, this shift function grows strictly sub-linear with respect to the time and then the shifted rarefaction wave is equivalent to the original self-similar rarefaction wave.

论文链接： http://dx.doi.org/10.1007/s00208-024-03083-5

成果二.

我院张世华研究员等与其合作者的论文 The Decoupling Concept Bottleneck Model 被 IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE 接收发表。

摘要：The Concept Bottleneck Model (CBM) is an interpretable neural network that leverages high-level concepts to explain model decisions and conduct human-machine interaction. However, in real-world scenarios, the deficiency of informative concepts can impede the model's interpretability and subsequent interventions. This paper proves that insufficient concept information can lead to an inherent dilemma of concept and label distortions in CBM. To address this challenge, we propose the Decoupling Concept Bottleneck Model (DCBM), which comprises two phases: 1) DCBM for prediction and interpretation, which decouples heterogeneous information into explicit and implicit concepts while maintaining high label and concept accuracy, and 2) DCBM for human-machine interaction, which automatically corrects labels and traces wrong concepts via mutual information estimation. The construction of the interaction system can be formulated as a light min-max optimization problem. Extensive experiments

expose the success of alleviating concept/label distortions, especially when concepts are insufficient. In particular, we propose the Concept Contribution Score (CCS) to quantify the interpretability of DCBM. Numerical results demonstrate that CCS can be guaranteed by the Jensen-Shannon divergence constraint in DCBM. Moreover, DCBM expresses two effective human-machine interactions, including forward intervention and backward rectification, to further promote concept/label accuracy via interaction with human experts.
论文链接： http://dx.doi.org/10.1109/TPAMI.2024.3489597

成果三.

我院张羊晶助理研究员等与其合作者的论文 On Efficient and Scalable Computation of the Nonparametric Maximum Likelihood Estimator in Mixture Models 被 JOURNAL OF MACHINE LEARNING RESEARCH 接收发表。

摘要：

In this paper, we focus on the computation of the nonparametric maximum likelihood estimator (NPMLE) in multivariate mixture models. Our approach discretizes this infinite dimensional convex optimization problem by setting fixed support points for the NPMLE and optimizing over the mixing proportions. We propose an efficient and scalable semismooth Newton based augmented Lagrangian method (ALM). Our algorithm outperforms the state-of-the-art methods (Kim et al., 2020; Koenker and Gu, 2017), capable of handling $n \approx 10^6$ data points with $m \approx 10^4$ support points. A key advantage of our approach is its strategic utilization of the solution's sparsity, leading to structured sparsity in Hessian computations. As a result, our algorithm demonstrates better scaling in terms of m when compared to the `mixsqp` method (Kim et al., 2020). The computed NPMLE can be directly applied to denoising the observations in the framework of empirical Bayes. We propose new denoising estimands in this context along with their consistent estimates. Extensive numerical experiments are conducted to illustrate the efficiency of our ALM. In particular, we employ our method to analyze two astronomy data sets: (i) Gaia-TGAS Catalog (Anderson et al., 2018) containing approximately 1.4×10^6 data points in two dimensions, and (ii) a data set from the APOGEE survey (Majewski et al., 2017) with approximately 2.7×10^4 data points.

论文链接：https://jmlr.org/papers/volume25/22-1120/22-1120.pdf

成果四.

我院 Panu Lahti 副研究员的论文 A sharp lower bound for a class of non-local approximations of the total variation 被 MATHEMATISCHE ANNALEN 接收发表。

摘要：We study a class of non-local functionals that was introduced by Brezis et al. (Atti Accad Naz Lincei Rend Lincei Mat Appl 33(2):413-437, 2022), and can be used to characterize functions of bounded variation. We give a new lower bound for the liminf of these functionals, involving the three different parts of the total variation, with sharp coefficients.
论文链接： http://dx.doi.org/10.1007/s00208-025-03101-0

成果五.

我院丁超副研究员等与其合作者的论文 A quadratically convergent semismooth Newton method for nonlinear semidefinite programming without generalized Jacobian regularity 被 MATHEMATICAL PROGRAMMING 接收发表。

摘要：We introduce a quadratically convergent semismooth Newton method for nonlinear semidefinite programming that eliminates the need for the generalized Jacobian regularity, a common yet stringent requirement in existing approaches. Our strategy involves identifying a single nonsingular element within the Bouligand generalized Jacobian, thus avoiding the standard requirement for nonsingularity across the entire generalized Jacobian set, which is often too restrictive for practical applications. The theoretical framework is supported by introducing the weak second order condition (W-SOC) and the weak strict Robinson constraint qualification (W-SRCQ). These conditions not only guarantee the existence of a nonsingular element in the generalized Jacobian but also forge a primal-dual connection in linearly constrained convex quadratic programming. The theoretical advancements further lay the foundation for the algorithmic design of a novel semismooth Newton method, which integrates a correction step to address degenerate issues. Particularly, this correction step ensures the local convergence as well as a superlinear/quadratic convergence rate of the proposed method. Preliminary numerical experiments corroborate our theoretical findings and underscore the practical effectiveness of our method.

论文链接： http://dx.doi.org/10.1007/s10107-025-02198-0

成果六.

我院骆顺龙研究员等与其合作者的论文 Broadcasting of imaginarity 被 PHYSICAL REVIEW A 接收发表。

摘要：Recently, the resource theory of imaginarity was proposed, viewing the imaginary part of a quantum state as a basic resource leading to quantum advantages. As with other quantum resources such as correlations, coherence, and asymmetry, a natural question arises: Can imaginarity resource be broadcast by a real operation which is free in the resource theory of imaginarity? In this work, we introduce two concepts of imaginarity broadcasting. The first pertains to nonreal states, while the second is related to the imaginarity resource. For nonreal states, we demonstrate that a specific type of nonreal states can be broadcast. However, when it comes to broadcasting the imaginarity resource, we get a surprising result that any imaginarity resource can be perfectly broadcast via a real operation. By comparing different (no-)broadcasting theorems, we distinguish the resource theory of imaginarity from the resource theories of correlations, coherence, and asymmetry, and reveal certain distinctive features of the resource theory of imaginarity.

论文链接： http://dx.doi.org/10.1103/PhysRevA.110.052439

成果七.

我院朱湘禅研究员等与其合作者的论文 Large N limit and 1/N expansion of invariant observables in O(N) linear σ-model via SPDE 被 PROBABILITY THEORY AND RELATED FIELDS 接收发表。

摘要：

In this paper we continue the study of large N problems for the Wick renormalized linear sigma model, i.e. N-component Φ^4 model, in two spatial dimensions, using stochastic quantization methods and Dyson–Schwinger equations. We identify the large N limiting law of a collection of Wick renormalized $O(N)$ invariant observables. In particular, under a suitable scaling, the quadratic observables converge in the large N limit to a mean-zero (singular) Gaussian field denoted by $\mathcal{Q}$ with an explicit covariance; and the observables which are $2n$-th renormalized powers of the fields converge in the large N limit to suitably renormalized n-th powers of $\mathcal{Q}$. The (Wick renormalized) quartic interaction term of the model has no effect on the large N limit of the field Φ, but has nontrivial contributions to the limiting law of the observables, and the renormalization of the n-th powers of $\mathcal{Q}$ in the limit has an interesting finite shift from the standard one. Furthermore, we derive the $1/N$ asymptotic expansion for the k-point functions of the quadratic observables by employing graph representations and analyzing the order of each graph from Dyson–Schwinger equations. Finally, turning to the stationary solutions to the stochastic quantization equations, with the Ornstein–Uhlenbeck process being the large N limiting dynamic, we derive here its next order correction in stationarity, as described by an SPDE with the right-hand side having explicit fixed-time marginal law which involves the above field $\mathcal{Q}$.

论文链接： http://dx.doi.org/10.1007/s00440-025-01361-0

成果八.

我院骆顺龙研究员等与其合作者的论文 Construction and classification of all equioverlapping measurements in qubit and qutrit systems 被 PHYSICAL REVIEW A 接收发表。

摘要：The overlap between quantum measurement operators is a fundamental quantity, and the notion of an equioverlapping measurement captures a symmetric feature of quantum measurements in terms of overlap. Such equioverlapping measurements, as a special class of quantum measurements, interpolate between von Neumann measurements and symmetric informationally complete positive operator-valued measures (SIC-POVMs), and exhibit a rich and subtle structure. In this work, we classify and completely determine all equioverlapping measurements in qubit and qutrit systems.

论文链接： http://dx.doi.org/10.1103/PhysRevA.111.012430

成果九.

我院王勇研究员等与其合作者的论文 High-quality sika deer omics data and integrative analysis reveal genic and cellular regulation of antler regeneration 被 GENOME RESEARCH 接收发表。

摘要：

The antler is the only organ that can fully regenerate annually in mammals. However, the regulatory pattern and mechanism of gene expression and cell differentiation during this process remain largely unknown. Here, we obtain comprehensive assembly and gene annotation of the sika deer (*Cervus nippon*) genome. We construct, together with large-scale chromatin accessibility and gene expression data, gene regulatory networks involved in antler regeneration, identifying four transcription factors, *MYC*, *KLF4*, *NFE2L2*, and *JDP2*, with high regulatory activity across the whole regeneration process. Comparative studies and luciferase reporter assay suggest the *MYC* expression driven by a cervid-specific regulatory element might be important for antler regenerative ability. We further develop a model called combinatorial TF Oriented Program (cTOP), which integrates single-cell data with bulk regulatory networks and find *PRDM1*, *FOSL1*, *BACH1*, and *NFATC1* as potential pivotal factors in antler stem cell activation and osteogenic differentiation. Additionally, we uncover interactions within and between cell programs and pathways during the regeneration process. These findings provide insights into the gene and cell regulatory mechanisms of antler regeneration, particularly in stem cell activation and differentiation.

论文链接： http://dx.doi.org/10.1101/gr.279448.124